Coalesc. of IMBHs: Implications for LISA (and the Big Bang Observer)

Pau Amaro-Seoane

http://www.aei.mpg.de/~pau

Max-Planck Institut fuer Gravitationsphysik (Albert Einstein-Institute)

Wednesday June 21, 2006 - Dynamics around a central BH

Collaborators

(1)

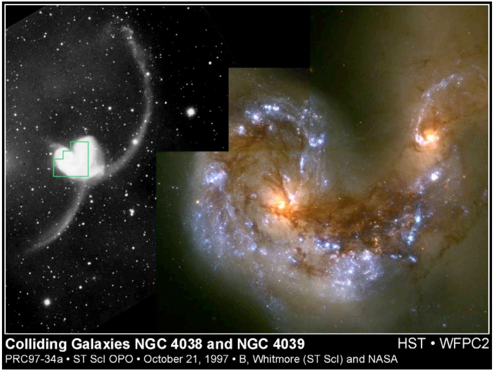
(2)

(1) Marc Freitag (IoA, Cambridge) -wine-

(2) L.C. Titan, 32 (micro) Grapes boards nodes (ARI, Heidelberg) -flops-

1.- Scenario

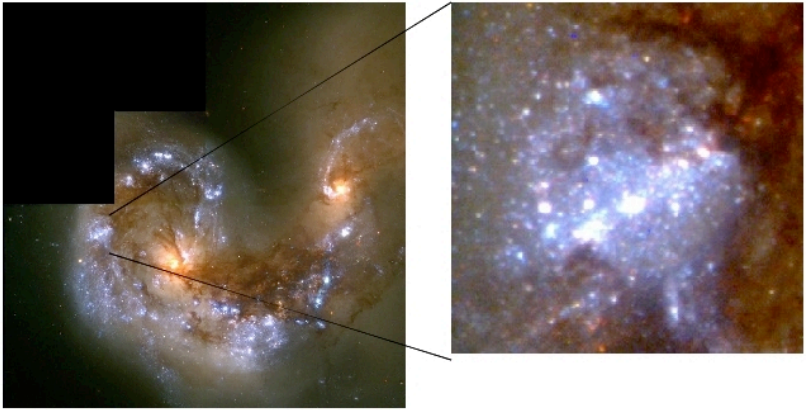
Physical scenario



Crash of galaxies NGC4038 and NGC4039

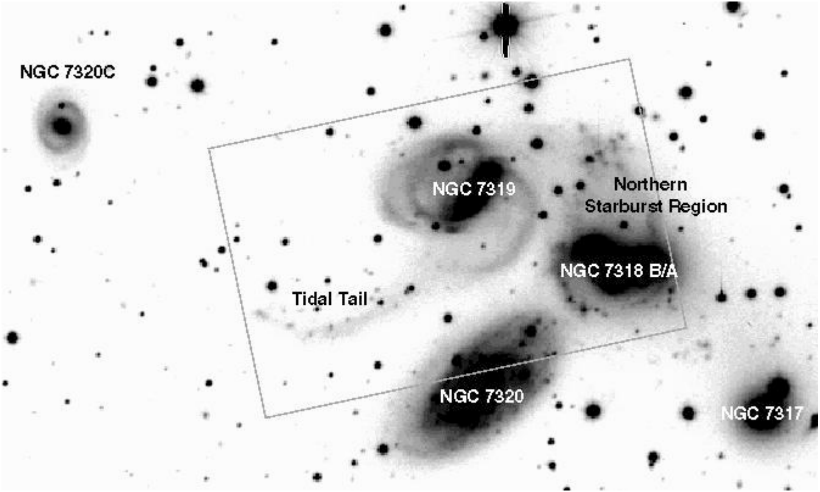
- Hierarchical models $\rightsquigarrow$ formation structures, down to galaxies
- Galaxies at least one merger
- A famous good example $\longrightarrow$ The Antennæ
- Young massive star clusters form in such perturbed-gas- rich enviroments (HST)
- Gas piles up in the centre $\longrightarrow$ collision $\longrightarrow$ grav unstabil. $\longrightarrow$ SF
- SF simul. suggest result collision of two clouds $\longrightarrow$ binary stel cluster

Zomming in: Star cluster complex, a cluster of clusters



Whitmore et al (1999)

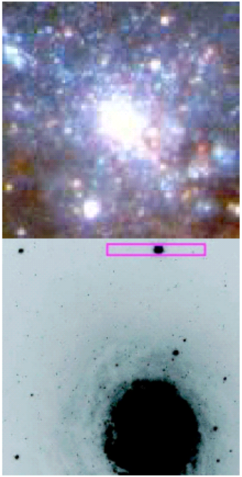
Stephan's Quintet

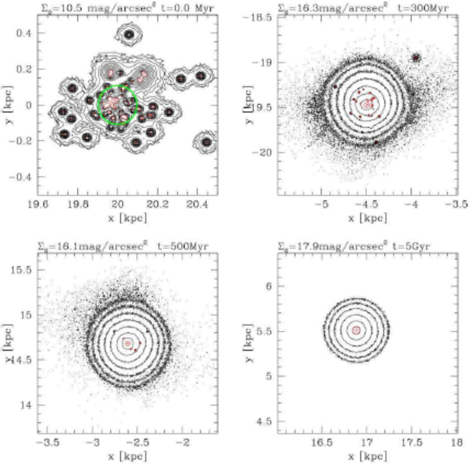


(Gallagher et al, `astro-ph/0104005`)

Formation of W3 in NGC7252 as prod of clust mergers

75 stell clusters, red dots = cores





Courtesy of M Fellhauer

2.- Merger of clusters

How to make two clusters merge

- NBODY4 + GRAPE6 hardware

  actually micro = single PCI cards, peaking at **130 Gflops**; *real* DR-GRAPEs = 2 **Petaflops**; $\sim$ 2008
- Up to 130k $\mathcal{N}_\star$
- The most accurate thing we can do: Direct summation NBODY (purely Newtonian)
- Relativistic situations?

  PN-body code

$$E = \underbrace{E_0}_{\text{Newt.}} + \underbrace{\underbrace{c^{-2}E_2}_{1\mathcal{PN}} + \underbrace{c^{-4}E_4}_{2\mathcal{PN}}}_{\text{periastron shift}} + \underbrace{\underbrace{c^{-5}E_5}_{2.5\mathcal{PN}}}_{\text{grav. rad.}} + \mathcal{O}(c^{-6})$$

How to make two clusters merge

- NBODY4 + GRAPE6 hardware

  actually micro = single PCI cards, peaking at **130 Gflops**; *real* DR-GRAPEs = 2 **Petaflops**; $\sim$ 2008

- Up to 130k $\mathcal{N}_\star$
- The most accurate thing we can do: Direct summation NBODY (purely Newtonian)
- Relativistic situations?

  PN-body code

$$F = \underbrace{F_0}_{\text{Newt.}} + \underbrace{\underbrace{c^{-2}F_2}_{1\mathcal{PN}} + \underbrace{c^{-4}F_4}_{2\mathcal{PN}}}_{\text{periastron shift}} + \underbrace{\underbrace{c^{-5}F_5}_{2.5\mathcal{PN}}}_{\text{grav. rad.}} + \mathcal{O}(c^{-6})$$

How to make two clusters merge

- NBODY4 + GRAPE6 hardware

  actually micro = single PCI cards, peaking at **130 Gflops**; *real* DR-GRAPEs = 2 **Petaflops**; ∼ 2008
- Up to 130k $\mathcal{N}_\star$
- The most accurate thing we can do: Direct summation NBODY (purely Newtonian)
- Relativistic situations?

  PN-body code

$$\underline{F} = \underbrace{\underline{F}_0}_{\text{Newt.}} + \underbrace{\underbrace{c^{-2}\underline{F}_2}_{1\mathcal{PN}} + \underbrace{c^{-4}\underline{F}_4}_{2\mathcal{PN}}}_{\text{periastron shift}} + \underbrace{\underbrace{c^{-5}\underline{F}_5}_{2.5\mathcal{PN}}}_{\text{grav. rad.}} + \mathcal{O}(c^{-6})$$

How to make two clusters merge

- NBODY4 + GRAPE6 hardware

  actually micro = single PCI cards, peaking at **130 Gflops**; *real* DR-GRAPEs = 2 **Petaflops**; $\sim$ 2008

- Up to 130k $\mathcal{N}_\star$
- The most accurate thing we can do: Direct summation NBODY (purely Newtonian)
- Relativistic situations?

PN-body code

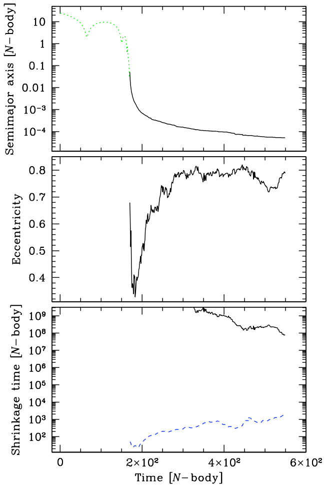
$$\underline{F} = \underbrace{\underline{F}_0}_{\text{Newt.}} + \underbrace{\underbrace{c^{-2}\underline{F}_2}_{1\mathcal{PN}} + \underbrace{c^{-4}\underline{F}_4}_{2\mathcal{PN}}}_{\text{periastron shift}} + \underbrace{\underbrace{c^{-5}\underline{F}_5}_{2.5\mathcal{PN}}}_{\text{grav. rad.}} + \mathcal{O}(c^{-6})$$

Mergers of clusters

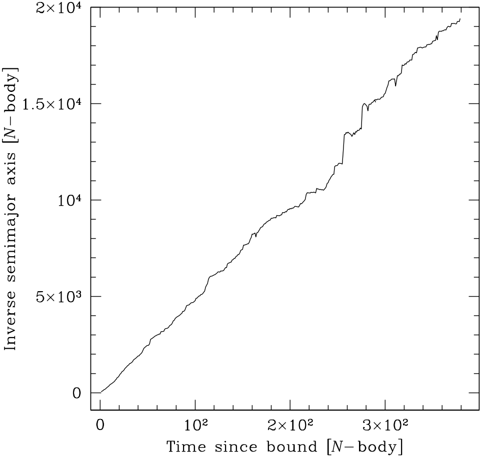
Parabolic orbit — Pericentre distance 2 pc — rel. vel. at pericenter of $23.3\mathrm{km\,s}^{-1}$ — Initial centre separation 2 pc — Initial rel. vel. $6.62\mathrm{km\,s}^{-1}$ — $\mathcal{M}_{\mathrm{cl}} = 6.3 \times 10^4 \mathrm{M}_\odot$ — $\mathcal{N}_{\mathrm{part}} = 6.3 \times 10^4$ — King models

Parameters evolution

Two king models, 126k $\mathcal{N}_\star$, $Wo|_1 = 6$, $Wo|_2 = 7$



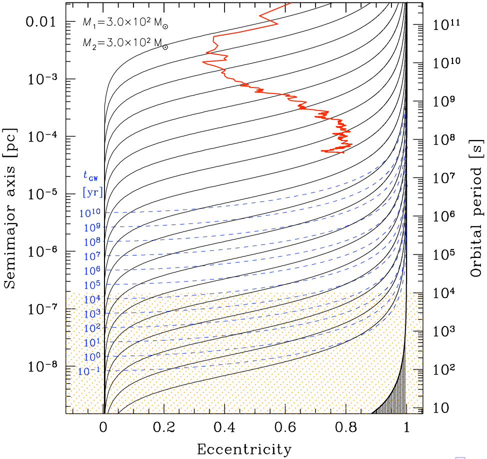
Inverse of the semi-major



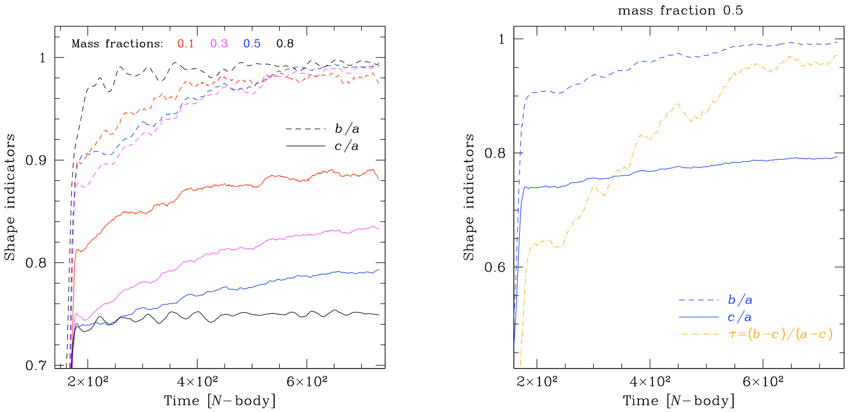
$\mathcal{U}_{\mathrm{T}}^{\mathrm{NB}} \sim 0.04$ Myrs

GW inspiral à la Peters and Matthews

$$t_{\rm GR} = 1.16\,{\rm Gyr} \left[\frac{a}{1\,{\rm mpc}}\right]^4 \left[\frac{\mathcal{M}_{1\bullet}\mathcal{M}_{2\bullet}(\mathcal{M}_{1\bullet}+\mathcal{M}_{2\bullet})}{(10^6\,{\rm M}_\odot)^3}\right]^{-1} \frac{1}{F(e)},$$
$$F(e) = (1-e^2)^{-7/2}\left(1 + 73/24e^2 + 37/96e^4\right)$$



BTW... a few words on triaxiality



System **oblate**: $\sim$ no triaxiality $\rightarrow$ no boxy orbits $\rightarrow$ not enough centrophilic orbits $\rightarrow$ hang-up danger for gal. nucl. (here we have low $\mathcal{N}_\star \rightarrow t_{\rm relax}/t_{\rm dyn}$ small)

3.- Implications for LISA/BBO ?

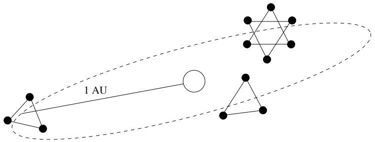
4 small LISAs

- BBO: Proposed space-born GW mission background early Universe, follow-on to LISA

  Phinney et al. 2003, C. Ungarelli et al., 2005
- Of all waves GWs interact the least: Undisturbed info from earliest moments Universe
- GWs *escaped* on a journey to us from age of 10^{-35} sec
- Design target: Detect primordial GWs in $10^{-1} < f < 1$ Hz
- At longer periods confus foregrd hopelessly large
- LISA not suitable; complet. covered by foreground WD^2
- At periods of 0.1-10 sec opportunity; primary source of foregrd NS^2 -few enough, can be identified and removed-

  Cutler & Harms 05

BBO parameters



Four constell, three satel (4 LISAs)
Heliocentric orbits @1AU from Sun
2 constell David star
2 ahead and behind $2\pi/3$ rad

	Symbol	Value
Laser power	P	300 W
Mirror diameter	D	3.5 m
Optical efficiency	ϵ	0.3
Arm length	L	$5 \cdot 10^7$ m
Wavelength of laser light	λ	$0.5\,\mu\mathrm{m}$
Acceleration noise	$\sqrt{S_{\rm acc}}$	$3 \cdot 10^{-17}\ \mathrm{m}/(\mathrm{s}^2\sqrt{\mathrm{Hz}})$

BBO and the Neutron-Star-Binary Subtraction Problem

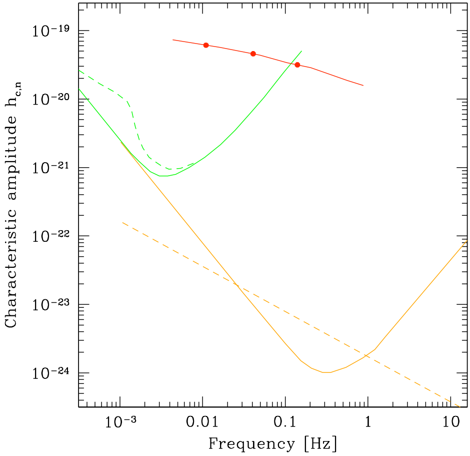
Curt Cutler[1] and Jan Harms[2]

[1]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109*
[2]*Max-Planck-Institut für Gravitationsphysik and Universität Hannover, Callinstraße 38, 30167 Hannover, Germany*

(Dated: November 22, 2005)

The Big Bang Observer (BBO) is a proposed space-based gravitational-wave (GW) mission designed primarily to search for an inflation-generated GW background in the frequency range $\sim 10^{-1}$ Hz $-$ 1 Hz. The major astrophysical foreground in this range is gravitational radiation from inspiralling compact binaries. This foreground is expected to be much larger than the inflation-generated background, so to accomplish its main

LISA/BBO sensitivity curve et al.



Coal $10^2 - 10^4\ \mathcal{M}_\bullet$ last year of insp (30D, 1D, 1H) @1Gpc

BBO, LISA

green dashed = inst noise + conf (WD^2)

orange dashed = NS^2 foreground

How many of such events?

→ Source for LISA! / Foreground for BBO?

$\boxed{\texttt{The moral of the story}}$

- IMBHs could form in glob clust, located in star complexes
- They will very probably collide
- NBODY simulations + PN corrections, how many merge? param dist?
- Estimate rates → Where in the LISA/BBO window? How significant?
- Could it be a source/foreground for LISA/BBO?

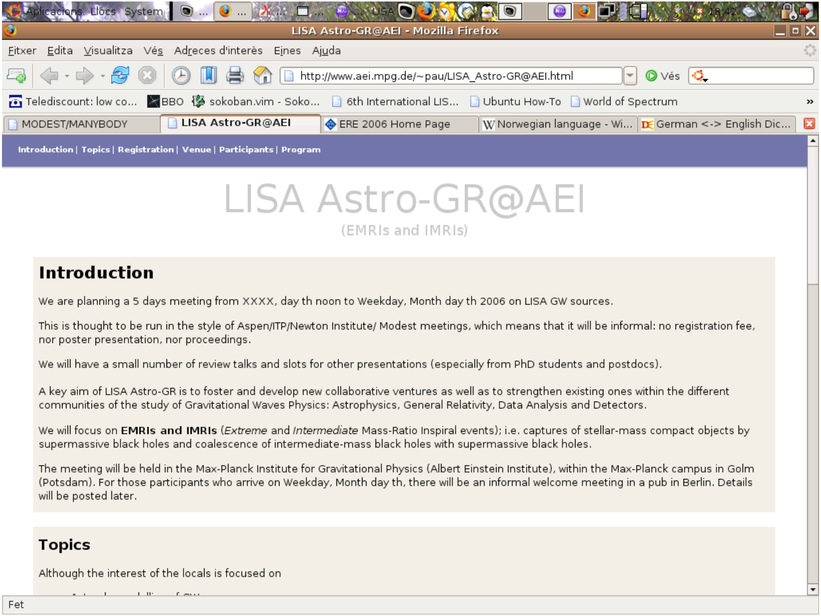
- IMBHs could form in glob clust, located in star complexes
- They will very probably collide
- NBODY simulations + PN corrections, how many merge? param dist?
- Estimate rates → Where in the LISA/BBO window? How significant?
- Could it be a source/foreground for LISA/BBO?

- IMBHs could form in glob clust, located in star complexes
- They will very probably collide
- NBODY simulations + PN corrections, how many merge? param dist?
- Estimate rates → Where in the LISA/BBO window? How significant?
- Could it be a source/foreground for LISA/BBO?

- IMBHs could form in glob clust, located in star complexes
- They will very probably collide
- NBODY simulations + PN corrections, how many merge? param dist?
- Estimate rates → Where in the LISA/BBO window? How significant?
- Could it be a source/foreground for LISA/BBO?

- IMBHs could form in glob clust, located in star complexes
- They will very probably collide
- NBODY simulations + PN corrections, how many merge? param dist?
- Estimate rates → Where in the LISA/BBO window? How significant?
- Could it be a source/foreground for LISA/BBO?

4.- One advertisement


LISA Astro-GR@AEI - Mozilla Firefox
Fitxer Edita Visualitza Vés Adreces d'interès Eines Ajuda
http://www.aei.mpg.de/~pau/LISA_Astro-GR@AEI.html
Vés
Telediscount: low co... BBO sokoban.vim - Soko... 6th International LIS... Ubuntu How-To World of Spectrum
MODEST/MANYBODY
LISA Astro-GR@AEI
ERE 2006 Home Page
Norwegian language - Wi...
German <-> English Dic...
Introduction | Topics | Registration | Venue | Participants | Program
LISA Astro-GR@AEI
(EMRIs and IMRIs)
Introduction
We are planning a 5 days meeting from XXXX, day th noon to Weekday, Month day th 2006 on LISA GW sources.
This is thought to be run in the style of Aspen/ITP/Newton Institute/ Modest meetings, which means that it will be informal: no registration fee, nor poster presentation, nor proceedings.
We will have a small number of review talks and slots for other presentations (especially from PhD students and postdocs).
A key aim of LISA Astro-GR is to foster and develop new collaborative ventures as well as to strengthen existing ones within the different communities of the study of Gravitational Waves Physics: Astrophysics, General Relativity, Data Analysis and Detectors.
We will focus on EMRIs and IMRIs (Extreme and Intermediate Mass-Ratio Inspiral events); i.e. captures of stellar-mass compact objects by supermassive black holes and coalescence of intermediate-mass black holes with supermassive black holes.
The meeting will be held in the Max-Planck Institute for Gravitational Physics (Albert Einstein Institute), within the Max-Planck campus in Golm (Potsdam). For those participants who arrive on Weekday, Month day th, there will be an informal welcome meeting in a pub in Berlin. Details will be posted later.
Topics
Although the interest of the locals is focused on
Fet